Industrial Crops and Products 32 (2010) 381–388

Contents lists available at ScienceDirect

Industrial Crops and Products

journal homepage: www.elsevier.com/locate/indcrop

Seed yield in kenaf (*Hibiscus cannabinus* L.) as affected by sowing time in South Italy

C. Patanè[a,*], O. Sortino[b,1]

[a] CNR-Istituto per i Sistemi Agricoli e Forestali del Mediterraneo (ISAFOM), Sede di Catania, Str.le V.Lancia, Zona Industriale, Blocco Palma I, 95121 Catania, Italy
[b] Dipartimento di Scienze Agronomiche, Agrochimiche e delle Produzioni Animali (DACPA), Università degli Studi di Catania, Via Valdisavoia 5, 95123 Catania, Italy

ARTICLE INFO

Article history:
Received 4 March 2010
Received in revised form 1 June 2010
Accepted 1 June 2010

Keywords:
Kenaf
Sowing time
Seed yield
Stem yield
Photoperiod
Thermal time

ABSTRACT

Kenaf is an interesting crop for fibre production, which has recently received great attention as a multi-purposes crop for energy, paper pulp, thermal insulation boards and fibre-reinforced thermoplastic composites production, etc., in Mediterranean countries. Its high sensitivity to photoperiod limits seed production to the semi-arid environments of Southern Europe. In order to investigate the effects of sowing time on seed yield of kenaf in the Mediterranean climate, a 2-year research was carried out in Sicily (South Italy) adopting cv. Tainung 2, under no water restriction (100% evapotranspiration – ET_c restoration) throughout the whole growing season. Four sowings per year were carried out, from late May to late June–early July. Flowering took place in a rather restricted period (late September–early October) irrespective of sowing date, confirming a strong daylength control over floral initiation. Thermal time calculated for the interval 'plant emergence (E)–flowering (F)', on average 1900.6 °Cd, decreased from the first to the last sowing date in both years, as an effect of photoperiod. The photoperiodic sensitivity (PS), calculated regressing thermal time 'E–F' against photoperiod at flowering time and equal to 497.21 °Cd h, can be considered as thermal time to flowering controlled by photoperiod. A base vegetative phase (BVP) of 1563 °Cd and a critical photoperiod (CP) of 13.94 h were calculated for cv. Tainung 2. The photoperiod inductive phase (PIP), which describes the effect of photoperiod on flowering time and varied between 497.2 and 182.2 °Cd h, allowed to predict the date of flowering with certain reliability, with values differing, in the worst case, 2 days only from the observed date.

With late May sowings, the crop produced a final dry biomass (>27 t ha^{-1}) significantly greater than that obtained with the following sowings, which approximated 15 t ha^{-1} in late June–early July sowings. Seed yield was negatively affected by the shift of sowing time, decreasing from over 3.5 to less than 1.6 t ha^{-1} due to a cut in number of pods per plant. According to the results of this research, early sowings of kenaf are suggested in semi-arid areas of South Italy for both seed and biomass production, maximum seed yield corresponding to maximum biomass yield, and with this last achieved with sowings of late May. The identification of both thermal and photoperiodic requirements to achieve high levels of seed yield in kenaf may help to individuate areas of seed production other than South of Italy, where however similar climatic conditions must be ensured to the crop.

1. Introduction

Kenaf (*Hibiscus cannabinus* L.) is an interesting crop for fibre production, which has recently received great attention as a multi-purposes crop for energy (Alexopoulou et al., 2004), pulp (Baldwin and Graham, 2006), thermal insulation boards and fibre-reinforced thermoplastic composites production (Ardente et al., 2008; Lips et al., 2009) in Mediterranean countries. Kenaf has been used as a raw material alternative to the wood in pulp production and paper industries, and in the textile industry (Ardente et al., 2008). In this last case the economic product of kenaf is the stem material, consisting of the outer bark (bast) which produces a high quality pulp, also suitable for both textile and technical uses (to make ropes, cordages, sacs, canvases, carpets, etc.) (Coetzee et al., 2008). Moreover, the inner part of the plant (core), rich of cellulose and hemicellulose, may be a source for the production of bio-ethanol of second generation (Cosentino et al., 2008), and is applicable as an adsorbent animal bedding material (Lips et al., 2009).

After the new rules of the EU Common Agricultural Policy (CAP) which does not indicate any crop to cultivate, kenaf may be a possible alternative to the traditional crops, such as hemp. Indeed, the improvement of its agronomic management allows its cultivation

* *Corresponding author*. Tel.: +39 095292873; fax: +39 095292870.
E-mail addresses: cristinamaria.patane@cnr.it (C. Patanè), o.sortino@unict.it (O. Sortino).
[1] Tel.: +39 095234412.

0926-6690/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.indcrop.2010.06.002

in many areas different than the native one, at least for biomass production.

Although kenaf is a high water-demanding crop (Amaducci et al., 2000), water stress is not always injurious, since it sometimes improves the quality of plant products. Moreover, the crop is able to recover following re-watering (Muchow, 1992). Kenaf is described as opportunistic in relation to water availability, with a high rate of stomatal conductance and transpiration rate when water is not limited, and a markedly reduced stomatal conductance and transpiration rate when water availability is restricted (BIOKENAF Booklet, 2007).

Constraints to the cultivation of this warm season species, originating from tropical areas near equator, are found in the high temperature requirements, which impose the sowing of the crop when minimum temperature goes beyond 12 °C (Angelini et al., 1998).

Due to its tropical origin, kenaf behaves as a short-day plant remaining vegetative until daylength falls below 12 h (Carberry et al., 1992) or 12 h and 45 min (Alexopoulou et al., 2000). Flowering of late-maturity cultivars is under photoperiodic control; conversely, photoperiod does not influence the flowering of early-maturity cultivars (Alexopoulou et al., 2000), which, however, are less productive in terms of final biomass (Foti et al., 1998; Alexopoulou et al., 2000).

Since kenaf is an annual crop, seeds are needed in continuously supply (Ten and Wong, 2006). However, the high sensitivity of this species to daylength makes quite difficult to produce seed in Europe, and limits its cultivation to this purpose to semi-arid environments of Southern Europe, where light and temperature conditions are the most favourable for seed maturation (Liu and Labuschagne, 2009). In fact, because of its tropical origin, the seeds require a period of frost free conditions to achieve the physiological maturity for germination. In Northern Europe, late floral initiation makes difficult to produce mature seed prior to a killing frost. Therefore, in an European context, the key limiting factor for kenaf to reach its great potential is the availability of seeds in large amounts. Similarly, in the United States seed production for late-maturity cultivars is limited to Southern States (Florida, California, Arizona) (Meints and Smith, 2003).

The sensitivity to photoperiod affects the choice of the most suitable cultivar and sowing time and, as a consequence, harvest time as well. Therefore, seed production is always feasible for the early varieties, while for the late ones seed production depends on the prevailing climatic conditions during autumn (Alexopoulou et al., 2000).

Kenaf has been extensively studied in different Italian conditions (Di Candilo et al., 1992; Gherbin et al., 1994; Petrini et al., 1994; Angelini et al., 1998; Amaducci et al., 2000). However, it has been displayed how cultivars of kenaf less sensitive to photoperiod and therefore able to flower even at high latitudes, when cultivated in central Italy produce seeds of low quality due to rapid deterioration and high susceptibility to fungal pathogens (Angelini et al., 1998). Moreover, sensitivity to low temperature during germination has been found to increase in most cultivars, so that germination percentages decrease as compared to that of seeds produced under lower latitudes. This fact is mainly due to the unfavourable conditions of temperature and moisture under which seed filling occurs.

Seed availability is requested for the wide spreading of the crop for biomass production in the European countries. Seed production of kenaf is also economically important since it is a good source of oil (16–22%) (Di Candilo and Faeti, 1990). Kenaf oil is characterized by a fatty acid composition very similar to that of cottonseed oil. It is comparable to most common edible oils and is excellent oil for human consumption. Furthermore, the high concentration of phospholipids (3.9–10.3%), greater than that of soybean (1.5–3.0%) and cottonseed (<2.0%), makes kenaf oil suitable for industrial uses (Mohamed et al., 1995). The seeds can also be used for cooking (flour) and lubrication, soap manufacture, cosmetics, linoleum, varnishes (Coetzee et al., 2008). It has been suggested that kenaf might be a profitable oil seed crop if yields of 1.2 t ha^{-1} could be obtained (Mohamed et al., 1995).

In this paper, the results of 2 years of field experiments conducted in the South-Eastern coast of Sicily (South Italy) on a cultivar of kenaf, concerning the effects of sowing time upon seed yield, are reported. This study aimed at identifying the most appropriate sowing time in kenaf to maximize seed production when cultivated under a typically Mediterranean climate.

Table 1
Characteristics of the upper soil layer (0–50 cm) of the experimental site.

Soil characteristic	Value
Sand (%)	37.0
Silt (%)	25.0
Clay (%)	38.0
pH (in water solution)	8.5
Total N (‰)	1.6
P_2O_5 avail. (mg kg^{-1})	52.3
K_2O avail. (mg kg^{-1})	325.0
Total calcareous (%)	28.5
Organic matter (%)	2.6
Bulk density (g cm^{-3})	1.2
Field capacity at −0.03 MPa (g g^{-1} dry weight)	0.33
Wilting point at −1.5 MPa (g g^{-1} dry weight)	0.16

2. Materials and methods

2.1. Field experiments

Experiments were conducted in the 2-year 2000–01 in eastern Sicily, South Italy, on a coastal site of Ragusa province (altitude: 10 m above sea level, latitude: 36°44′N, and longitude: 14°51′E) in a typical Xerochrepts-calcixerollic Xerochrepts-lithic Xerorthents soil (USDA, 1999). In Table 1 the soil characteristics of field site are reported. Eight sowings were carried out in total, from late May to early July (Table 2). The late-maturity cv. Tainung 2 (Danalatos and Archontoulis, 2004) of kenaf was adopted for the experiments.

A randomised complete block experimental design with four replicates was adopted and a plant density of 100 000 plants ha^{-1} (0.5 m between rows and 0.2 m within rows) was planned. This last was lower than plant density conventionally adopted at sowing for biomass production of kenaf (200 000–300 000 plants ha^{-1}, Alexopoulou et al., 2004; Baldwin and Graham, 2006; BIOKENAF Booklet, 2007) since in the experiment the crop was mainly addressed to seed production and plants were widely spaced to this end in order to achieve successful pod ripening (Foti et al., 1998). Single plot surface measured 15 m^2 (5.0 m × 3.0 m). Before sowing, 50 kg ha^{-1} of N (as ammonium sulphate), 100 kg ha^{-1} of P (as mineral perphosphate) and 100 kg ha^{-1} of K (as potassium sulphate) were distributed. Approximately a month after sowing, a further 50 kg ha^{-1} of N (as ammonium nitrate) was supplied as top dressing.

A drip irrigation system was used for irrigation. This last was determined on the basis of the maximum available soil water con-

Table 2
Sowing dates in the 2 years of experiment.

Year	Sowing date			
2000	May 28	June 8	June 19	June 30
2001	May 24	June 13	June 23	July 5